Current Research



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The Food Propensity Questionnaire: Concept, Development, and Validation for Use as a Covariate in a Model to Estimate Usual Food Intake

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ABSTRACT

Objective Twenty-four—hour recalls capture rich information on food consumption, but suffer from inadequately measuring usual intakes of episodically consumed foods. We explore using food frequency questionnaire (FFQ) data as covariates in a statistical model to estimate individual usual intakes of episodically consumed foods and their distributions and describe the development of the Food Propensity Questionnaire, an FFQ introduced in the 2003-2004 National Health and Nutrition Examination Survey.

Design We analyzed data from 965 adult participants in the Eating at America's Table Study who completed four 24-hour recalls and an FFQ. We assessed whether or not

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0002-8223/06/10610-0011\$32.00/0 doi: 10.1016/j.jada.2006.07.002 increasing FFQ-reported frequency was associated with both number of 24-hour recall consumption days and amounts reported.

Results For 52 of 56 food groups (93%), and 218 of 230 individual foods (95%), there were significant monotonically increasing relationships between FFQ frequency and 24-hour recall probability of consumption. For 47 of 56 food groups (84%) and 55 of 230 (24%) individual foods, there were significant positive correlations between FFQ frequencies and consumption-day mean intake.

Conclusions We found strong and consistent relationships between reported FFQ frequency of food and food-group consumption and probability of consumption on 24-hour recalls. This supports the premise that frequency data may offer important covariate information in supplementing multiple recalls for estimating usual intake of food groups.

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ietary guidance in the United States is focused on the consumption of food over time (1), and national dietary goals, such as Healthy People 2010 (2), are framed in terms of proportion of the population meeting specified average daily amounts of foods or food groups. Between 1994 and 2002, the national data used to assess how closely individuals' intakes meet dietary recommendations or how closely the population meets dietary goals consisted of two detailed 24-hour dietary recalls conducted in a large population-based survey, the Continuing Survey of Food Intakes by Individuals (CSFII) (3), and one recall from the 1999-2002 National Health and Nutrition Examination Survey (NHANES) (4). Although 24-hour recalls capture rich information on a person's food consumption, this dietary assessment method suffers from difficulties in adequately measuring the usual intake of foods that are not consumed nearly every day (ie, episodically consumed foods). Even when two 24-hour

recalls are collected, the probability of consumption for most foods is poorly captured at the individual level.

These limitations led us to consider using statistical modeling to combine food frequency questionnaire (FFQ) data with a limited number of 24-hour recalls. The essential element of an FFQ is precisely that which the 24-hour recalls lack—that is, the probability of consumption, queried as frequency of usual intake over a specified time period (often, "in the past year"). On the other hand, FFQs do not provide adequately detailed information about amounts consumed because they crudely query portion size, assign standard portion sizes to estimate nutrient intakes, and ask respondents to report their average portion size over a long period of time. In comparison, 24-hour recall methodology attempts to correctly quantify portion size for each eating occasion.

The idea of including frequency-type questions in national dietary surveillance is not new. A varying number of intake days and FFQs occasionally have been included in dietary surveys to better assess usual intakes for particular foods or food groups of interest (1-6). For example, between 1971 and 1994, NHANES included frequency questionnaires that varied in terms of food and foodgroup specificity, the reference period, and the frequency response categories. NHANES I and NHANES II included frequency questions covering all major foods and food groups consumed over a 3-month reference period (5,6). The Hispanic Health and Nutrition Examination Survey (7) also used a 3-month reference period, but its frequency questions covered a more extensive food list that targeted dietary sources of vitamins A and C and fat. The NHANES III frequency questionnaire used a "past month" reference period and targeted dietary sources of vitamins A and C, calcium, caffeine, and fat (8).

Why one would even consider combining frequency data from an FFQ with high-quality recall data in a statistical model for purposes of improving national dietary surveillance is a fair question. After all, FFQs, which are considered the only practical and affordable dietary assessment method for purposes of measuring usual intake in large epidemiologic studies, are known to exhibit a significant amount of measurement error (9-12). The nutrition community has exhibited considerable skepticism about the accuracy with which individuals can recall and report a year's worth of food intake, and the resulting output for absolute intake of nutrients and food groups. However, our approach, presented by Tooze and colleagues (13), does not use the absolute frequencies reported by respondents as individual measures of frequency of intake. It requires only that the FFQ frequency information be related to the 24-hour recall information with respect to an individual's probability of consuming a particular food.

We looked to a well-established FFQ—the Diet History Questionnaire (DHQ) (14), sponsored by the National Cancer Institute and currently among many FFQs used in nutrition epidemiologic research as a springboard from which to develop an instrument to use in a statistical model with recall data in the 2003-2006 NHANES. The food list for the DHQ was established using data from the US Department of Agriculture's 1994-1996 CSFII (15). The format, wording, and order were established through extensive cognitive testing (16). In addition, the DHQ was

assessed in three validation studies. Two of these studies (9,10,17) assessed the validity of the estimates of nutrient intakes derived from the DHQ and are not applicable to how well an FFQ might perform in statistical modeling of usual food intake as described by Tooze and colleagues (13). The third study (18) assessed the validity of estimates of frequency of food intake only; therefore, the findings are more applicable to our proposed new use of an FFQ. We describe all the validation studies briefly, both as an indication of the level of scrutiny the DHQ has undergone and to acknowledge problems with FFQs in general.

The first validation study, the Eating at America's Table Study (17), indicated that, in measuring nutrient intakes, the DHQ was as good as or better than two other widely used FFQs available at the time; the estimated average correlation coefficient between 25 nutrients (energy adjusted) and "truth" was 0.63 for women and 0.65 for men (range 0.36 to 0.81), assuming four 24-hour recalls as the unbiased reference instrument in a measurement error model assessing energy-adjusted intake of nutrients (12).

The second validation study, the Observing Protein and Energy Nutrition Study (9,10), assessed the structure of measurement error in the DHQ with respect to absolute intake of energy, protein, and energy-adjusted protein using unbiased biological measures as the reference. The findings indicated significant measurement error, both random and systematic, with respect to absolute intakes.

The results of the Checklist Validation Study (18) are most relevant to assessing food consumption probability because they relate to frequency of intake only. For 30 days, respondents completed a checklist (the reference instrument), recording frequency of intake of selected food items. After completing the checklist, these respondents filled out an early version of the DHQ, which queried frequency of intake during the past month. Results showed consistently high agreement (>85%) between the reference instrument and ever-vs-never consumption across nine food groups in the DHQ. Results also showed modest to high correlations ($r \ge 0.5$) of frequency of consumption for most foods and food groups. Although the study was limited to 30 days and the DHQ was completed after the subjects had recorded their frequency of intake of a limited number of foods daily, these relationships, which indicated high agreement for probability to consume, were considered adequate for consideration in the model by Tooze and colleagues (13).

Using frequency data from an FFQ as covariates in statistical models directed at estimating usual intake of episodically consumed foods requires not that the frequency information be precise, but rather that it exhibit a strong and predictive relationship with 24-hour recall data with respect to an individual's probability to consume a particular food. If, in addition, it has a relationship with the amounts reported on a 24-hour recall, this might provide additional information. The purposes of this report are to quantify this relationship and determine if it supports the concept of using an FFQ as a covariate in the statistical model described by Tooze and colleagues (13), and to describe the development and application of an FFQ for this purpose in the NHANES 2003-2006.

METHODS

Study Description

We used data from the Eating at America's Table Study, described in detail elsewhere (17), to assess the relationship between reported DHQ frequency and both probability of consumption of a particular food or food group on a given day and the amount consumed on consumption days using four 24-hour recalls. The Eating at America's Table Study, which began in August 1997, incorporated nationally representative sampling and random-digit dialing techniques to obtain and recruit participants. Each participant completed four telephone-administered 24hour recalls during 1 calendar year (one recall per season). At the end of the year in which the 24-hour recalls were collected, participants completed the DHQ. A total of 965 respondents (60%) completed all four 24-hour recalls and a DHQ that met criteria for acceptability. This study was approved by the National Cancer Institute Special Studies Institutional Review Board.

The 24-hour recalls were collected using the multiplepass methodology developed for the 1994-1996 CSFII (3). The DHQ used in the Eating at America's Table Study was a 36-page booklet querying frequency of intake for 124 individual food items with average portion size indicated in three ranges. The instrument took about 1 hour to complete (19). Additional embedded questions were asked about related factors for about one third of the items queried resulting in 143 items on the instrument. These included queries on seasonal intake, proportion of consumption of specific types of food, and/or fat uses or additions. A copy of the instrument used in the Eating at America's Table Study can be downloaded from http://riskfactor.cancer.gov/DHQ.

Creation of Food Intake Variables

Each of the 4,062 unique food codes used in coding the 24-hour recalls in the Eating at America's Table Study was placed into one of 184 groups of nutritionally and cognitively similar foods. Of these, 143 had been selected for inclusion in the DHQ based on earlier analyses that indicated they were the most important contributors to total intakes of energy, fat, vitamin C, beta carotene, dietary fiber, vitamin A, calcium, or vitamin E (20). These 143 food groups represented line items on the DHQ and were referred to on the instrument as either individual foods (such as "cheese") or as food groups (such as "pancakes, waffles, or french toast"), which contain nutritionally or cognitively similar foods. Hereafter, we refer to the 143 groups created from the 24-hour recall data as "DHQ food groups." For example, all 24-hour recall food codes for bread were grouped into two DHQ food groups: white bread or whole-grain-containing bread.

Because of our interest in evaluating foods and food groups important in dietary guidance and singled out for goals, such as dark-green vegetables (2), we also created Pyramid food group variables (21) from the DHQ food groups from 24-hour recalls by using the Pyramid Servings Database (22). For example, the recall data showed that four DHQ food groups—broccoli, cooked greens, raw greens, and salads—together contributed 85% to total intake of dark-green vegetables. Some DHQ food groups represent food mixtures, which could contribute to mul-

tiple Pyramid food groups. For example, chili contributes to total meat, legumes, tomatoes, and total vegetables, and cakes, cookies, and brownies contribute to grains, discretionary fat, and added sugar. Finally, we looked at the proportion each DHQ food group contributed to total intake of each Pyramid food group. Those top DHQ food groups whose cumulative proportion was at least 85% of the total amount of any Pyramid food group reported on 24-hour recalls by Eating at America's Table Study subjects were considered in the analyses of Pyramid food groups in this study.

The premise we investigated is whether or not frequency data from an FFQ, without portion size, can provide useful covariate information in a statistical model that estimates usual food intake from two 24-hour recalls. Therefore, in our analyses of the Eating at America's Table Study data, we excluded the portion size information and used only the frequency data from the DHQ.

Data Analyses

We first assessed the relationship between DHQ frequencies of eating a particular food and 24-hour-recall reports of eating the same, by sex of respondent. A report on the 24-hour recall refers to any mention of the food; the number of times the food is mentioned and the amounts are not considered. All frequency responses from the DHQ were converted to average daily frequencies for both individual line items and Pyramid food groups. Individual line item frequencies were reported as one of 10 or 11 discrete categories for beverages and foods, respectively, on the DHQ, ranging from zero to six or more times per day for beverages and zero to two or more times per day for foods. For some individual line items, embedded questions were asked regarding proportion of the time (eg, almost never or never, about one quarter of the time, about half the time, about three quarters of the time, almost always, or always) these foods were consumed as varying types, such as low-fat vs regular-fat luncheon meats or whole-grain vs non-whole-grain breads. These proportions were applied to the frequencies of the individual line items. Then, response category frequencies were converted to a daily average (eg, a report of one time per week was converted to one seventh times per day). It is important to note that some DHQ response categories were not selected by any respondent. For example, no one in the Eating at America's Table Study reported consuming broccoli two or more times per day.

For Pyramid food groups, daily frequencies for individual DHQ line items were summed to calculate a total daily frequency. For example, frequencies for the individual line items broccoli, cooked greens, raw greens, and salad were summed to determine a total daily frequency of Pyramid servings of dark-green vegetables. Because the summed Pyramid food-group variables had a more continuous distribution than the single DHQ line items, frequency reports of zero were placed into one group and all nonzero frequencies were placed into deciles.

We restricted this analysis to 117 of the 143 individual DHQ food groups and 28 of the 30 Pyramid food groups. We did not analyze the Pyramid food groups for discretionary fat and added sugar because they are consumed daily by almost everyone, and therefore, an FFQ would not be expected to add a significant amount of informa-

tion to what is provided by 24-hour recalls alone. Consistent with this decision, 26 of 143 DHQ food groups were excluded because they contributed only to discretionary fat or added sugar (such as butter, margarine, sugar). We then found that two DHQ food groups (soymilk in cereal and poultry cold cuts, such as turkey bologna) were never reported on the Eating at America's Table Study recalls and thus were not usable, leaving a total of 115 DHQ food groups for analysis.

To analyze the relationship between frequencies on the DHQ and reports of consumption on 24-hour recalls, we first investigated the relationship between frequency of foods (line items) on the DHQ and probability of consumption of DHQ food groups on four 24-hour recalls. We hypothesized that the probability of reported consumption of a particular food on four 24-hour recalls, which has discrete values of 0, 0.25 (1 day out of 4 days), 0.5 (2 days out of 4 days), 0.75 (3 days out of 4 days), and 1.0 (all 4 days), would tend to increase with increasing DHQ frequency reports of that food. We assessed this aggregate level tendency using the nonparametric Jonckheere-Terpstra test (23). For our purposes, $P \le 0.05$ for this test indicates that people with a high vs low DHQ frequency are more likely to report consumption on multiple days and, hence, have a higher probability of consumption on any given day.

Second, we assessed the relationship between DHQ frequency and the amount (expressed as Pyramid servings) reported on any 24-hour recall consumption day. Our hypothesis was that people who reported high frequency of consumption of a food on the DHQ would, as a group, consume larger amounts of that food on 24-hour recalls than those with lower DHQ-reported frequency. Dodd and colleagues (24) have shown for several food groups that the average consumption-day amount for individuals who consumed on more days tends to be higher than the average consumption-day amount for individuals who consumed on fewer days. We assessed whether or not DHQ frequencies were related to amounts consumed on recalls by calculating the Spearman correlation between the ranked DHQ frequencies and the ranked individual consumption-day mean intakes of DHQ food groups on the 24-hour recalls.

RESULTS

Eating at America's Table Study respondents were approximately evenly divided by sex and ranged in age from 20 to 60 years. About 80% were white, 10% African American, and 5% Latino. Most (75%) had more than a high school education.

Figure 1 compares daily frequency reported on the DHQ to probability of consumption on four 24-hour recalls among men for three example food groups (ie, whole grains, dark-green vegetables, and citrus/melon/berries) and three individual foods (ie, broccoli, canned tuna, and apples). These six were selected because they represent a range of foods and food groups consumed in varying frequencies or because they are of public health interest. The findings for women are similar (data not shown). For the individual foods, the size of the circles represents the number of respondents in each frequency group. In the case of food groups, the circles are the same size because the frequencies were divided into deciles as described

previously. A very small circle, such as that found in the figure for Vegetables (Dark Green), represents those few individuals with no reported frequency of intake of that food or food group on the DHQ. The scales on the graphs are different for each example because both frequency and probability vary widely among the foods. For 52 out of the 56 food groups (93%) and for 218 out of 230 individual foods (95%), the Jonckheere-Terpstra test was significant ($P \le 0.05$), indicating a monotone increasing relationship between DHQ frequency and 24-hour recall probability of consumption on a given day. Most of these tests (92%) had a P < 0.0001. All examples in Figure 1 illustrate significant relationships. Individual foods for which the test was not significant were those rarely consumed, such as soy milk in cereal, liver, stuffing, ground poultry, and pecan pie. The four food groups for which the test was not significant occurred in men and can be characterized as either rarely consumed (eg, organ meats) or so ubiquitously consumed (eg, total grains, non-whole grains, and total vegetables) that the probability is nearly always one on the recalls even though the daily frequency on the DHQ has considerable variation. The first case reflects too little information, and the second reflects constant probability of consumption.

Figure 2 shows the comparison of daily frequencies reported on the DHQ to amounts expressed as Pyramid servings consumed that were averaged from four 24-hour recalls, also for men. For 47 out of 56 food groups (84%) Spearman correlations were positive and significant $(P \le 0.05)$, indicating that large DHQ frequencies are associated with increasingly large consumption-day mean intake. This is demonstrated by the three food groups illustrated. For individual foods only 54 out of 230 (24%) had significant Spearman correlations; five were negative. The range of significant correlation coefficients, in terms of absolute values, was 0.10 to 0.80; with an interquartile range of 0.20 to 0.36. The range for nonsignificant correlations (0.00 to 0.70) overlaps that for significant ones, and the interquartile range is 0.04 to 0.15. Another 19 foods had P values between 0.05 and 0.10. In Figure 2, broccoli and tuna show significant positive correlations ($P \le 0.05$) between frequency and amount, but apples do not.

DISCUSSION

These findings show strong and consistent relationships for the majority of foods and food groups examined between reported frequency of consumption based on an FFQ and probability of consumption on four 24-hour recalls. This supports our premise that an individual's frequency reports on an FFQ may be useful as a predictor of his or her probability of consumption, a factor/characteristic that cannot be assessed with only a few recalls. Conceptually, this means that it may be possible to first model the relationship between 24-hour recall probabilities and FFQ frequencies at the aggregate level and then predict probability of consumption at the individual level. This supports the use of these frequency data to supplement, not supplant, recall data collected in national surveillance.

As to whether or not frequency reports may offer any additional benefit in better estimating amounts consumed, our results showed that the relationship between

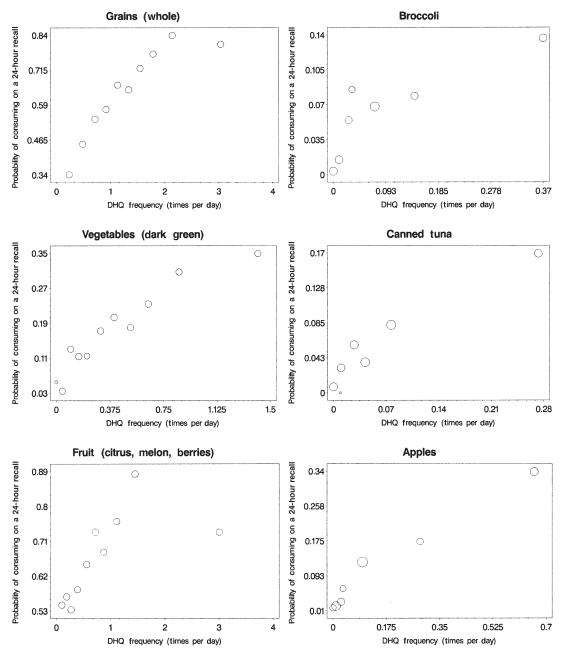


Figure 1. Diet History Questionnaire (DHQ) frequency vs 24-hour recall probability among men. All examples represent significant relationships (P<0.0001). (Data from this figure are available online at www.adajournal.org as part of a PowerPoint presentation featuring additional online-only content.)

frequency and amount is not necessarily evident for individual foods. Although this relationship simply may not exist for some individual foods, for others it is possible that the relationship exists but cannot be discerned from only four 24-hour recalls. This may be because ranks of individual 4-day means do not accurately reflect the ranks of the usual amounts consumed on a daily basis (a repercussion of the large within-individual variability discussed at length in Dodd and colleagues [24]). Another consideration is that foods like apples that are usually

consumed as single units are less likely to exhibit variability in portion size no matter how high the reported frequency.

The relationship between frequency and amount differed with respect to food groups. Here we showed that more often than not, a moderate to strong relationship between frequency and amount is observed. We chose to assess Pyramid food groups, but we could have applied our method to other food groups of interest by combining the daily frequencies of any number of individual DHQ

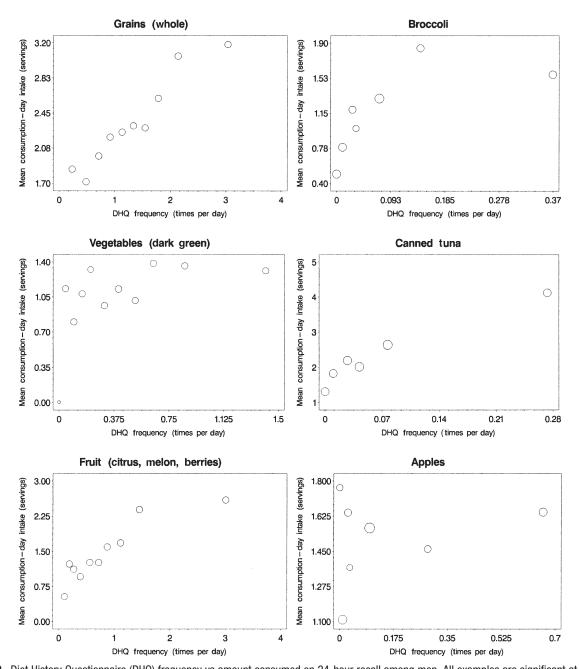


Figure 2. Diet History Questionnaire (DHQ) frequency vs amount consumed on 24-hour recall among men. All examples are significant at $P \le 0.05$, except for apples. (Data from this figure are available online at www.adajournal.org as part of a PowerPoint presentation featuring additional online-only content.)

foods and the findings would probably have been similar. Given that foods in food groups are often substituted for one another, we are more likely to observe intake of a food group on four recalls and, thus, to see the relationship if it exists. In any event, predicting probability is most important in modeling usual intake of episodically consumed foods; anything added by the correlation between frequency and amount will improve the model but may not be necessary.

A more complex model, like that presented by Tooze

and colleagues (13), may be able to detect an underlying relationship between probability and amount that this simpler analysis cannot. Whether or not that is the case, these findings indicate that the primary requirement for our intended use of frequency data in dietary surveillance—that is, as a covariate in a model where the main variables are amounts and frequencies of food as reported on two 24-hour dietary recalls—was met. An FFQ can only enhance the information obtained from recalls, not replace them.

Use of This Study's Findings in NHANES 2003-2006

The Food Propensity Questionnaire (FPQ) (available at http://riskfactor.cancer.gov/diet/adi/fpq.html) is the FFQ that was pilot-tested and incorporated into NHANES 2003-2006 for individuals aged 2 years and older. It contains 139 questions, some of which include additional embedded questions. Although our primary purpose in incorporating the FPQ into NHANES 2003-2006 was to assess diets in relation to the *Dietary Guidelines for Americans* (1) and the *Healthy People 2010* objectives (2), we retained most of the standard DHQ line items in the FPQ, even though each one was not necessarily tied to a dietary guideline or goal. We did so because some strengths of the DHQ are that it queries intake in a logical and understandable manner and conveys the sense that total diet is of interest.

To develop the FPQ for use in NHANES, we removed portion size questions and made some changes and modifications to the original DHQ questions. First, we investigated whether or not we had incorporated all the necessary food items for assessing important dietary goals for episodically consumed foods or food groups, such as dark-green vegetables or whole grains, by analyzing food sources of Pyramid food groups from the 1994-1996 CSFII. This led to some modifications/additions to line items, such as querying the proportion of the time "hot cereal" was oatmeal or how often "cooked grains" were whole grains.

Second, some of the DHQ questions regarding details of addition of fats and oils were removed, given that estimating usual intake of discretionary fat from recall data alone is fairly accurate because it is generally consumed daily by almost everyone. In addition, questions on frequency of intake of added fats, spreads, and oils are notoriously difficult to answer.

Third, because the DHQ was originally developed based on data from adults only from the CSFII (3), we analyzed 1994-1996 CSFII for children's sources of Pyramid food groups to assess the need to add foods consumed primarily by them. As a result, apple juice, grape juice, granola bars, and pudding/custard were added. Finally, we consulted with other federal government agencies regarding their specific data needs. Based on discussions with the US Food and Drug Administration, we added two questions about raw fish and raw milk.

In NHANES 2003-2006, the FPQ (available in both Spanish and English) was sent to all respondents aged 2 years and older after they completed the second 24-hour recall. Those not completing the second recall were not sent an FPQ. The instrument was intended to be self-administered for those aged 12 years or older. For children aged 2 to 5 years, a parent or guardian was to complete the instrument; for those aged 6 to 11 years, the FPQ was to be completed with assistance. Respondents were remunerated with \$30 after the questionnaire was returned.

Preliminary unweighted response rates for 2003-2004 indicate that for those aged 2 years or older (n=7,821) with dietary recall data, 80% returned the FPQ. Nine percent of those returned were completed in Spanish. The Table presents the response rates by demographic groups. Response rates are fairly uniform. Teenagers, followed by those aged 20 to 59 years, had the lowest response rates. FPQ returns by subjects with less than a

Table. Preliminary unweighted food propensity questionnaire response rates by demographic characteristics: National Health and Nutrition Examination Survey 2003-2004

	Response Rate (%) ^a	
Demographic group	Males	Females
Total (n=8,847) Age (y)	77	83
2-5	77	74
6-11	81	84
12-19	70	81
20-59	76	84
60+ y	87	89
Race/ethnicity		
Non-Hispanic white	82	86
Non-Hispanic African American	73	81
Mexican American	74	82
Education level ^b		
<high school<="" td=""><td>75</td><td>82</td></high>	75	82
High school	82	88
>High school	82	86
^a Percent of those completing two 24-hour recalls. ^b Based on 4,145 persons aged 20 years and older.		

high school education were five to six percentage points

lower than subjects with a high school education or more. Response rates to the self-administered FPQ were acceptable at approximately 80%. Without a doubt, respondents with low literacy will find it difficult to complete the FPQ unassisted. In addition, given past experience with FFQs, it is likely that frequency responses will be missing at random. Work is currently under way to determine if standard imputation techniques can be applied when analyzing FPQ data.

CONCLUSIONS

Our intended use of FFQ data is novel. The FPQ data will not be used to estimate absolute nutrient intake or frequency of food group intake—the usual use of FFQ data in epidemiologic research. Rather, the reported frequencies will be used solely as covariates in a two-part statistical model to enhance the estimation of usual intakes (13). Although individuals may try to describe their diets well when responding to an FFQ, as numerous studies show, they do so with substantial random and systematic error (9-12). Nevertheless, when individuals are grouped by frequency of reporting food groups, those frequencies exhibit a strong enough relationship with probability of consumption on 24-hour recalls to be considered for use as covariates in statistical modeling of usual intake from 24-hour recall data.

Both the FPQ instrument and frequency data from the FPQ used in NHANES 2003-2006 will be available on the World Wide Web for use by investigators. Further information regarding how to use two 24-hour recalls and the FPQ data in a model to determine usual intake of episodically consumed foods will be made available. This study demonstrated that data from the FPQ can be used as covariates when estimating usual intake of episodically consumed foods from 24-hour dietary recall data.

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